ON THE FORMATION OF THE ANNUAL RING ON THE SHELL OF THE ABALONE, HALIOTIS DISCUS var. HANNAI INO.

ON THE FORMATION OF THE ANNUAL RING ON THE SHELL OF THE ABALONE, *HALIOTIS DISCUS* var. *HANNAI* INO.

By

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Introduction

It has been reported that shells of *Cardium edule*, *Pecten yessoensis*, *P. maximus*, *Mactra sachalinensis*, and *Haliotis discus* var. *hannai* bear concentric annual or disturbance rings as a rhythmical growth mark. The concentric annual ring is frequently employed for age determination of these marine animals. However, there remain much to be cleared regarding seasons and conditions at which these rings are formed.

The writer carried out the rearing experiment of the abalone, *Haliotis discus* var. *hannai*, a commercially important gastropod in northern Japan, for the purpose of clearing the fundamental problem of age determination, and the results are reported in this paper.

Here the writer wishes to express his hearty gratitude to Prof. T. Imai, Assistant Prof. R. Sato and the staff of Onagawa Fisheries Laboratory, Tohoku University, for the direction and cooperation given during the experiment.

Materials and Method

The specimens were caught on the shore of Onagawa Bay, Miyagi Prefecture, Japan. In January 1954, eight specimens of the abalone from 5 to 6 cm in shell length were kept in a bamboo basket with the capacity of 0.04 cubic meter. The basket was suspended at two meters depth in water under a raft in the bay. As food brown algae, *Undaria pinnatifida* and red algae, *Pachymenia sp.* were used in the experiment. The algae were renewed occasionally during the rearing experiment.

In April 1955, the abalones were taken from the water and the shells were sectioned. Sections were 30 to 50 microns in thickness, and the concentric growth rings were checked under the microscope.

The counting of the concentric rings was also made with native abalones collected from Onagawa Bay and the neighboring Okachi Bay by using Taka-

yama's method (5), which count the cracks formed on the shell along the annual rings when the shell is burnt on a strong flame.

Results and Discussion

(1) Rearing experiment

The abalone shell is formed of three distinct layers, namely periostracum, prismatic layer and nacreous layer. Several concentric rings were observed in the shell of the reared abalone. There was noticed one ring which was more depressed deeply than others and could be distinguished easily from the other rings. As shown in Plate 1, the periostracum in this ring projected into the prismatic layer and its extension was impressed as a opaque fault plane in the nacreous layer. There was no doubt that the ring was formed in early September. As is shown in Table 1, this ring laid in the brown colored zone of the shell which was grown in the later part of the year. This type of ring was not observed in other seasons of the year. Therefore, this ring can be considered as an age mark of the shell.

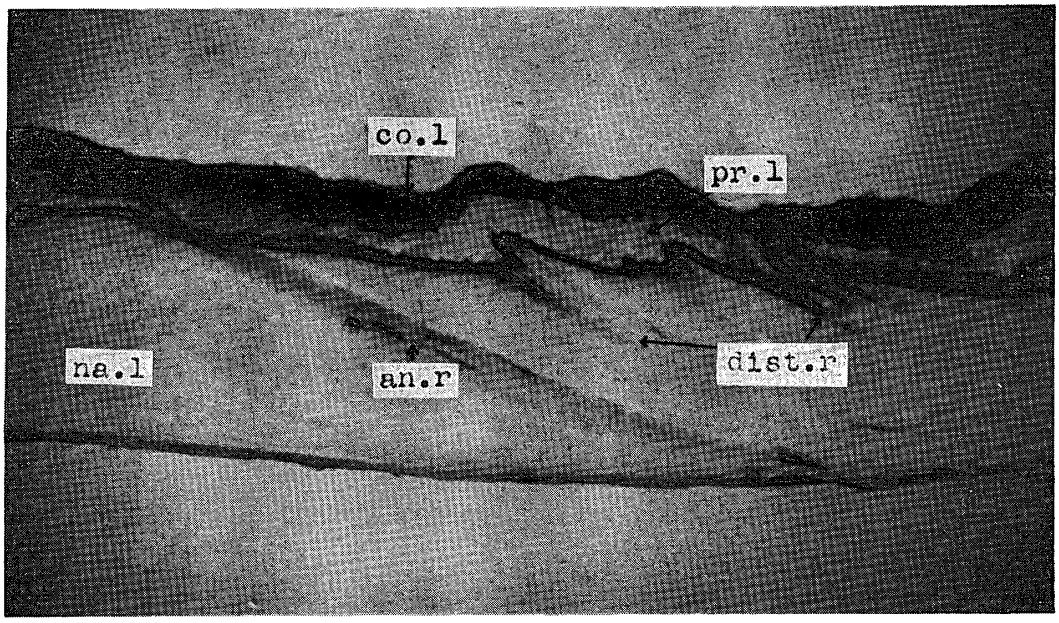

Plate 1. Section of the abalone shell.

co. 1 : periostracum
pr. 1 : prismatic layer
na. 1 : nacreous layer
an. r : annual ring
dist. r : disturbance ring

A growth curve of the abalone under rearing is shown in Figure 1. The shell grew steadily from January to July, but its growth was retarded in August, September and October. While the growth in weight was suspended in August to October, and it resumed growth again from November on.

Table 1. Formation of the concentric rings on the shell of the abalone under rearing.

kind of algae fed		brown algae	red algae	brown algae					red algae				brown algae		
color of shell		bluish-green	brown	bluish-green					brown				bluish-green		
group	indiv. no.	Jan. 22 -Feb. 21	Feb. 22 -Mar. 23	Mar. 24 -Arp. 23	Apr. 24 -May 15	May 16 -31	June 1 -30	July 1 -31	Aug. 1 -31	Sept. 1 -30	Oct. 1 -31	Nov. 1 -Dec. 12	Dec. 13 -Jan. 11	Jan. 12 -Feb. 14	Feb. 15 -Mar. 18	Mar. 19 -Apr. 18
A	1									◑○				◑	◑	
	2								◑	○						
	3								◑	○						
	5						◑	◑		○				◑	◑	◑
B	4							◑		◑○						
	6							◑	◑	◑	○					
	7							◑		◑○	◑					
	8									◑○				◑	◑	◑

(○……annual ring, ◑……disturbance ring)

Generally the abalone in Onagawa area spawnes in August and September, and under rearing in early September. Therefore, it is clear that the retardation in shell growth and the suspension in weight growth was due to the development of gonads and the shedding of the gamates. From the observation, it can be concluded that the formation of the annual ring is a result

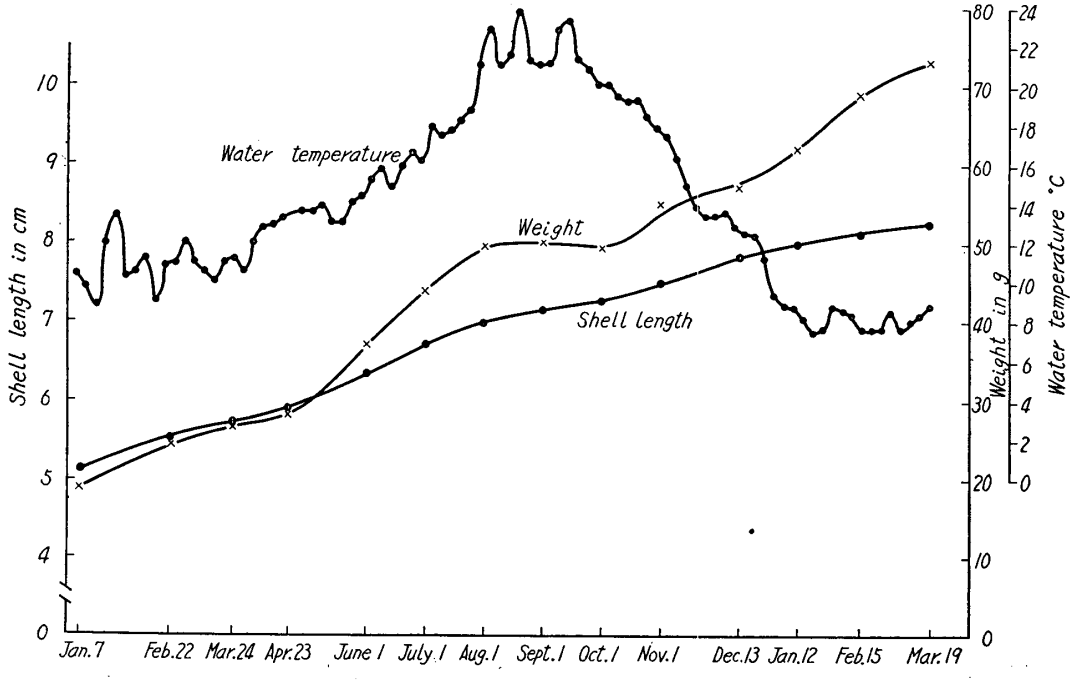

Fig. 1, Growth curve of abalone.

of temporal cessation of shell growth at the period of gonad maturation and spawning. Furthermore, this conclusion may be supported by the facts that no annual ring is clearly recognizable in the 0-year-old abalones which never became matured.

Besides the annual ring, the shell bears several concentric growth rings which are not so marked as the annual ring. The ring disappears as it approaches the nacreous layer. The record of formation of this type of rings in reared specimens are shown in Table 1. Their formation was initiated by exposing the specimens to air for less than 30 minutes which was often experienced in the case of renewing the food algae in the basket. Furthermore, it was observed that the disturbance rings were formed frequently during the spawning season and also more often in the older specimens than in the young ones. Therefore, it can be considered that the growth of the abalone is readily disturbed in the spawning season and in the older specimens by a slight change in the environmental conditions.

In the younger abalones, a remarkable disturbance ring was found only in the spawning season. It was also true with the younger abalones collected from the natural rock. While in the abalones above 7 cm in shell length, the number of disturbance rings was larger than in young ones. It was also true with the abalones reared in the experiment.

There remains a question whether a lack of the food could cause a ring formation. To make this point clear, a few specimens were isolated from a basket of Group A on July 1, and put into another basket (Table 1, Group B). They were fed on algae of (roughly) one-fifth of the amount normally required* until August 1. As food, brown algae, *Undaria pinnatifida* was used exclusively. Group B were returned to the basket of group A on August 1, and they were fed with sufficient amounts of algae. During the period of underfeeding three abalones formed the disturbance rings. It can be concluded that the shell growth of the abalones were disturbed by a shortage of food.

A change of food algae, from the brown algae to the red one or from the red algae to the brown, never caused the formation of disturbance rings throughout the experiment, as can be seen from Table 1.

(2) Observations on the annual rings of abalone in nature.

Materials were collected from the coast of Onagawa Bay and Okachi Bay, Miyagi Prefecture. For the purpose of ascertaining the season at which the annual rings were formed, the position of the ring in relation to the coloration of the shell, which differed by seasons according to the kind of algae consumed,

* The average rate of food consumption per day during this period was 16.5 per cent of the body weight.

were examined. In the shell of the one-year-old abalone it was difficult to identify the first annual ring and the change in coloration by season. Observation of the abalones collected from Onagawa Bay revealed that the annual rings are mostly seen at the point of change of coloration of shell from bluish-green to brown. The percentage of its occurrence was 49.7 (Table 2). While the percentage of occurence of the annual ring in brown zone was 41.7. However, very few rings were seen in the bluish-green zone or at the position of change from brown to bluish-green. The abalones collected from Okachi Bay showed the same tendency as in ones of Onagawa Bay.

Table 2. Occurence of annual rings in relation of the color zone of shells.

location	Onagawa Bay						Okachi Bay					
color of shell / annual ring	bluish-green →brown	brown zone	brown→ bluish-green	bluish-green zone	rings not identified	total number observed	bluish-green →brown	brown zone	brown→ bluish-green	bluish-green zone	rings not identified	total number observed
2nd ring	31	26	1	0	6	64	8	10	0	1	1	20
3rd ring	32	28	2	0	2	64	9	6	2	2	1	20
4th ring	24	19	1	3	0	47	4	1	1	3	0	9
Total	87	73	4	3	8	175	21	17	3	6	2	49
%	49.7	41.7	2.3	1.7	4.6	100.0	42.8	34.7	6.1	12.2	4.1	100.0

It was ascertained experimentally that coloration of the shell differed by species of algae consumed (unpublished). That is to say, when they took brown and green algae, the prismatic layer became bluish-green in color. On the other hand, when they took red algae, brown colored shells resulted. Brown algae, *Undaria* and *Laminaria* etc., are the most rich food for native abalones in northern Japan but they wither in the middle August. Thereafter, the abalone feed mainly on red algae, *Pachymenia sp.* and *Carpopeltis affinis* etc. From these evidences it can be safely concluded that the annual ring of these abalone in nature developed in September. The result coincides well with that of the rearing experiment.

Mason (3) found that the ring in the shell of *Pecten maximus* is formed in the spring. Yamamoto (6) studied the growth of the surf clam (*Mactra sachalinensis*), and found that a ring of this shell was formed in the period between November and April, and said that the ring formation might be caused by a disturbance in shell growth following the depression of water temperature.

The experiments and observations here presented proved clearly that in the Japanese abalone, *H. discus* var. *hannai* Ino, only one annual ring with distinguished feature is formed at their spawning season, and its formation

is caused by the temporary suspension in shell growth at the season of gonad maturation and spawning. Therefore, it can be concluded that the annual ring is a proper character to be used to determine the age.

Summary

(1) The rearing experiments and the observations were made with an abalone, *Haliotis discus* var. *hannai*, to study the formation of annual and disturbance rings in the shell.

(2) One ring of distinguished feature was formed in the spawning season, in September. This can be called an annual ring and can be used to determine the age of shell.

(3) Abalone grew from November to July, but the growth was suspended in August and September.

(4) It is considered that the formation of an annual ring was due to the temporal suspension of the shell growth during the season of the gonad maturation and spawning.

(5) Besides annual ring, disturbance rings developed several times in a year. They were readily formed by a change in the environmental conditions, such as an exposure to air and temporal deficiency in food.

(6) Microscopic observations on the annual and disturbance rings were described in the paper.

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